Remote Sensing of Urban Land Use and Effects on Climate

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The urban heat island effect exists as a "dome" of elevated temperatures that presides over cities, primarily in summertime, in contrast to their rural surroundings. The occurrence of urban heat islands reflects the human-induced contrasts between rural and urban areas caused by alteration or replacement of the "natural" environment (e.g., trees) surrounding the city with generally nonevaporating and nonporous materials, such as pavements and buildings. This results in reduced evapotranspiration and more rapid runoff of rain water, as well as a general increase in temperatures over urban areas as opposed to their rural counterparts. Urban heat islands have caused changes in precipitation and temperatures over cities that are at least similar to, if not greater than, those predicted to develop over the next 100 years by global change models. Although the urban heat island has been well established for very large cities, such as New York City or Mexico City, there are little data to support the development of this phenomenon over small- to medium-sized cities of between 100,000 to 300,000 population and located in humid, temperate climatic regimes. Additionally, low-resolution satellite data used in past studies have not adequately captured the extreme heterogeneity of the urban landscape, which in part drives the development of the urban heat island. This research project, therefore, has sought to obtain a better understanding of the causes of the urban heat island across the heterogeneous urban landscape, and for a city of medium population size, through examining high-resolution airborne remote sensing data obtained over the Huntsville, AL metropolitan area.

Day and night airborne thermal infrared image data were collected at 5- and 10-m spatial resolutions over Huntsville on September 7, 1994, using the NASA Advanced Thermal and Land Applications Sensor (ATLAS). The ATLAS is a 15-channel scanner with 9 visible and middle and near-reflective infrared bands between 0.45 to 4.20 µm, and 6 thermal infrared bands in the 8.20 to 12.2 µm range. ATLAS data were acquired during the daytime between approximately 11 A.M. to 2 P.M. local time to capture the time of greatest solar incidence upon the urban surface around solar noon, and then again between about 9 p.m. to midnight to capture the time when the urban heat island phenomenon is most pronounced. These data were used to measure and model the state and changes in thermal responses from specific urban land cover types typical of the Huntsville metropolitan area to better measure and model how dynamics of city surface drive or force development of the urban heat island. Additionally, these data have been used to spatially model heating and cooling patterns as a means for visualizing how thermal responses are distributed across the Huntsville urban landscape.

Progress during the past year has focused on deriving a visualization model of heating and cooling patterns for the Huntsville area. Figure 150 represents ATLAS 10-m pixel spatial resolution data for daytime that have been draped on top of digital elevation model (DEM) data for a portion of the study area. Prominent features are Huntsville and Green Mountains on the right side of the image, Jones Valley located in the center of the image which is comprised of pasture land for grazing cattle, the low hills bordering Jones Valley on the left, and an urbanized area on the far left side of the image. This three-dimensional perspective is useful for developing a better perspective of daytime thermal energy (i.e., heating and cooling) patterns across the urban landscape and also for modeling the effects of slope and aspect on thermal energy responses. High thermal responses (or areas exhibiting higher temperatures) are represented in white with decreasing thermal responses shown in gray to black tones. Mountainous areas on the right side of the image exhibit relatively low thermal responses because of the extensive vegetation cover present (i.e., trees). Pasture land in Jones Valley expresses higher thermal energy responses because of factors related to the type of vegetation present (i.e., grass), the amount of area open to the sky for solar heating, and other factors. Considerably higher thermal energy responses are exhibited by

10 m Day Thermal (Band 13)

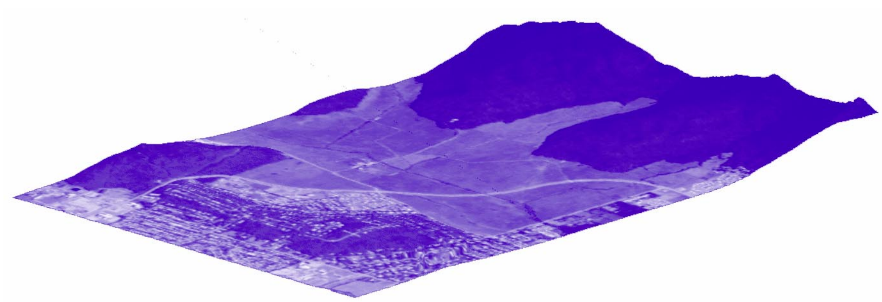

FIGURE 150.—Three-dimensional model of daytime ATLAS 10 m thermal remote sensing data draped on top of digital elevation model (DEM) data for a portion of the Huntsville metropolitan area.

the residential and urbanized areas bordering Jones Valley on the far left and center-facing side of the image. Figure 151 represents the same area as observed using nighttime ATLAS 10-m data. The mountains on the far right side of Jones Valley have relatively high thermal energy responses due to the effects of late afternoon solar incidence on the west-facing slopes. Some ground fog is evident as a haze creeping into the coves in Jones Valley adjacent to the mountains on the right side of the image. Pasture land in Jones Valley exhibits relatively low thermal responses because of the effects of the high availability of moisture in the form of dew and because of cold air drainage coming into the valley from the mountains, as well as other factors. The residential and urbanized area on the left and center-facing sides of the image are high in thermal energy responses at night because pavement, buildings and other impervious surfaces store heat during the day and begin to release this stored thermal energy after sunset.

As a result of the findings from this project, a research proposal submitted in response to NRA–95–MTPE–03, "Opportunities to Participate in NASA Mission to Planet Earth and Earth Observing System Science and Education Programs," has been funded to support a project entitled "A Remote Sensing-Based Study of Past and Future Land Use Change Impacts on Climate and Air Quality of the Atlanta, Georgia Metropolitan Region." This new research effort seeks to provide scientific understanding of the importance of urbanization as a forcing-function in local and regional climatic processed by analyzing how the rapid growth in the Atlanta metropolitan area over the last 25 years has impacted the climate and air quality of the region. Additionally, using information from the Atlanta Regional Commission on proposed growth of Atlanta in the next 20 years, this research will model how the proposed growth of the Atlanta metropolitan area will potentially affect the climate and air quality of the region.

Lo, C.P.; Quattrochi, D.A.; and Luvall, J.C.: "Application of High-Resolution Thermal Infrared Remote Sensing and GIS to Assess the Urban Heat Island Effect." *International Journal of Remote Sensing*. In press, 1996.

Lo, C.P.; Quattrochi, D.A.; Luvall, J.C.: "Detection Of Urban Heat Island Development Using High-Spatial Resolution Thermal Infrared Remote Sensing." *Proceedings*, vol. 1, Remote Sensing and Photogrammetry. American Society for Photogrammetry and Remote Sensing/American Congress on Surveying and Mapping Annual Convention and Exposition, April 22–25, Baltimore, MD, pp. 138–147, 1996.

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University/Industry Involvement: Dr. Chor-Pang Lo from the Department of Geography at the University of Georgia has been a direct collaborator in this research as a NASA summer faculty fellow at MSFC during 1994 and 1995.

Biographical Sketches: Dr. Dale Quattrochi is a geographer/research scientist within the Earth System Science Division, Global Hydrology and Climate Center of the MSFC Space Sciences Laboratory. His research focuses on analysis of land surface energy exchanges and their effect on climate and hydrologic processes using remote sensing data.

Dr. Jeffrey Luvall is a forest ecologist/research scientist within the MSFC's Space Sciences Laboratory's, Earth System Science Division, Global Hydrology and Climate Center. His research focus is also directed toward examining land surface energy fluxes and their effects on local and regional climate, and hydrology using remote sensing.

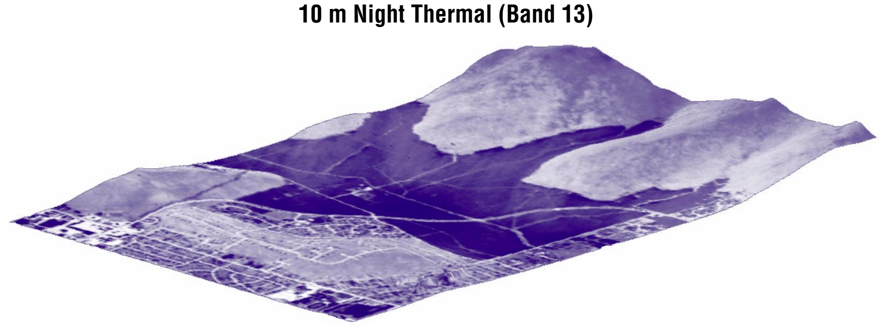

Figure 151.—Three-dimensional model of nighttime ATLAS 10 m thermal remote sensing data draped on top of digital elevation model (DEM) data for a portion of the Huntsville metropolitan area.